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PHYTOTOXICOLOGY SOIL INVESTIGATION:

AT PORT HOPE SCHOOLS

JULY 1996

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Report No: SDB-012-3511-97

Phytotoxicology Soil Investigation at Port Hope Schools: July 1996

Executive Summary

Surface soil was sampled from the main play areas of 12 Port Hope schools in July 1996. Uranium and arsenic concentrations were within the expected range at 11 of the 12 schools, based on previous studies conducted by the MOEE and the LLRAWMO. Soil antimony concentrations marginally exceeded the background-based OTR guideline at some play grounds at six schools. Surface soil at the north end of the Lions Recreation Centre park, which was sampled as the play ground for St. Mary's school, had lead and antimony concentrations that exceeded the health-based soil clean-up guidelines, and uranium, arsenic, barium, zinc, and strontium concentrations that exceeded the OTR guidelines. The source of this contamination is almost certainly historical disposal of foundry waste (*Crane, previously Standard Sanitary, not Cameco refinery waste*), municipal waste dumping, and general land filling in the park area that took place since before the turn of the century to about the mid 1940s. The extent of the contamination in the Lions Recreation Centre park is unknown, as only surface soil (0 to 5 cm) from the north end of the park was sampled.

The MOEE soil clean-up guideline for lead is targeted specifically at protecting young children, as they are more sensitive to the well known potential health effects of lead exposure. The potential health effects of antimony exposure on children are less clearly understood. Unlike buried radioactive contamination that can result in radon gas emissions at the surface, inorganic contamination (like lead and antimony) buried at depth does not create a potential health problem for children using the park as long as the surface soil layer is clean. Children are exposed to the contaminant by physical contact with contaminated soil, or through inhaling contaminated dust that gets stirred up by play activity or ground level winds. However, at least in the north end of the park where sampling was conducted, lead and antimony contamination exists in the surface soil and therefore children using the park during non-snow cover conditions are potentially at risk of exposure. Until subsequent sampling defines the extent and severity of surface soil contamination, restricting young children's access to the park may be warranted.

Phytotoxicology Soil Investigation at Port Hope Schools: July 1996

Background

Previous investigations by the Ontario Ministry of Environment and Energy[Ref.1] (MOEE), and the Low Level Radioactive Waste Management Office[Ref.2] (LLRAWMO) have documented that surface soil across a significant area of Port Hope is contaminated with uranium and arsenic and that specific areas have antimony and lead concentrations that are considerably above background. The uranium and arsenic contamination, which originated from historic atmospheric emissions from Cameco and it's predecessor companies, is confined to the upper 20 to 30 cm of soil and distributed across town in a clear concentration gradient that decreases with increasing distance from the uranium refinery. The origin of the soil lead and antimony contamination, which occurs both at the surface and at depth, is less certain but it is likely related to historical emissions and waste disposal from the old Crane foundry. This heavy metal contamination is specific to the area adjacent to the river mouth and at selected sites along Alexander St.

In a letter to the LLRAWMO dated March 21, 1996 the Port Hope Environmental Advisory Committee requested surface soil sampling of all 12 Port Hope schools. The LLRAWMO declined to initiate a soil sampling program because earlier LLRAWMO studies did not find unusual radon gas concentrations in any Port Hope schools (indicating that soil radionuclide contamination was unlikely) and because the schools were outside of the area of known elevated soil metal concentrations. The Committee then approached the Peterborough District MOEE office, who in turn asked the Phytotoxicology Section to consider this request. Since none of the 12 Port Hope schools were included in previous MOEE soil sampling programs the possibility of soil contamination, although believed to be unlikely, could not be categorically excluded. In a letter to the Port Hope Environmental Advisory Committee dated July 4, 1996, the author confirmed that the MOEE Phytotoxicology Section would conduct the requested soil sampling in the summer of 1996.

Project Scope

The soil sampling project was not intended to thoroughly characterize the soil chemistry at each school. It was a screening-level program to identify potential problem sites and to augment the existing environmental data for Port Hope. Only surface soil (0 to 5 cm in depth)

was sampled from the main play areas at each school. This surface soil layer is the material that the children contact and it is the origin of ground level dust that they inhale; therefore it represents the most direct potential exposure route to contaminated soil. Contamination at depth, if it exists, is not a concern for either contact or inhalation. Soil contamination detected at any of the schools by this screening-level program will be followed-up with additional sampling to define the extent and severity of contamination.

Sampling Collection

A list of 12 Port Hope schools was provided by Peterborough MOEE Environmental Officer Mike Longpre. The sampling was conducted on July 10, 1996 by Phytotoxicology Scientist Dave McLaughlin and Environmental Technicians Katherine Zeeman and Sonya Carl. Surface soil was collected in duplicate at 20 sites, for a total of 40 samples. A description of each sample site is summarized in Table 1.

The school properties varied considerably in size, therefore some schools had only one sample site and some schools had as many as three sites. Because this was a screening-level program only the major activity areas were identified and sampled; that is, areas where the children were most likely to congregate, stir up dust, and possibly come into physical contact with soil particles. Typically this meant soccer, football, and baseball fields, and around playground equipment. The descriptions provided in Table 1 are quite general, and are not intended to describe in detail the precise location of each sample. This is because the sample areas were often quite large. For example, football and soccer fields were sampled by collecting surface soil while walking the entire length of the field from goal post to goal post. This would comprise one of the duplicate pair of samples from each site. The process was repeated for the second of the duplicate sample pair. Similarly, baseball diamonds were sampled by walking in an arc around the inner playing field from first to third base. Soil near playground equipment was typically sampled by walking an entire circle around but immediately adjacent to the equipment. Where there was no playground equipment and no sports field on which to centre the sample, soil was collected while walking an "X" pattern from corner to corner of the yard. A Magellan global satellite positioning system was used to fix the centre of each sample site to a ground resolution of +/- 1 metre.

Each site was sampled in duplicate using standard Phytotoxicology soil sampling protocols[Ref.3] and equipment. The samples were collected into polyethylene bags, assigned unique

field numbers, and kept locked in the vehicle until they were delivered to the Phytotoxicology processing laboratory.

Sample Analyses and Interlab Comparison

The samples were processed at the Phytotoxicology Processing Laboratory shortly after collection. The processing included air drying, pulverizing, passing the homogenized soil through a 2 mm sieve, and then the sieved fraction was ground to pass through a 355 micron sieve. The processed samples were then split into two subsamples. One set of samples was to be forwarded to a private laboratory for analyses, and one set of samples was held for analyses by the MOEE Laboratory Services Branch (LSB).

In an effort to continue to meet community service expectations in a time of fiscal constraint, the MOEE is exploring co-operative ventures with the companies that are responsible for the community's environmental problems. Since Cameco and it's predecessor companies are responsible for most of the soil contamination in Port Hope, they were approached for assistance and agreed to contribute to the school sampling program by providing analytical resources. Cameco suggested that the samples go to a private laboratory rather than conduct the analyses in their own facility, as they thought this would be more acceptable to the community. MOEE's LSB was committed to a 25% audit of the samples sent to the private lab.

On October 21, 1996 the author received confirmation that Cameco had provided a purchase order to Monserco Limited to analyze 42 soil samples for uranium, arsenic, antimony, and lead. The processed soil samples, which had been in storage at the Phytotoxicology Processing Lab, were immediately forwarded to Monserco. The 42 samples included 40 from Port Hope plus two LSB QA/QC samples. At the same time 10 samples (the 25% audit, comprised of every fourth consecutively numbered sample sent to Monserco) were forwarded to LSB.

The results from Monserco were provided directly to the Phytotoxicology Section on December 6, 1996. The confirmatory LSB results were received February 20, 1997.

Monserco used the Slo-Poke reactor at the University of Toronto to conduct Neutron Activation Analyses (NAA) for the uranium, arsenic, and antimony analyses, and Flame Atomic Absorption Spectrophotometry (FAA) for the lead analyses. LSB used Inductively Coupled

Plasma - Mass Spectroscopy (ICP-MS) for the uranium analyses[Ref.4], Inductively Coupled Plasma Atomic Emission Spectrophotometry (ICP-AES) for lead[Ref.5], and Hydride Generation Flameless Atomic Absorption Spectrophotometry (HGFAA) for the arsenic and antimony analyses[Ref.6]. A sample by sample comparison of the results and a summary of a statistical analysis of the data from the two labs is summarized in Appendix 1. The descriptive statistics indicated that the two labs compared very well. The data sets were highly correlated for each element (r^2 ranged from 0.941 to 0.998). A paired t-test indicated that the population means for each pair of elements were not (statistically) significantly different.

The lead results were the most consistent between the two labs across the range of concentrations. The lead relationship was described by the regression equation:

Monserco lead = 1.0184*MOEE lead (forcing the intercept through 0).

The other three elements were slightly more variable at either the lower or higher concentration ranges. Their relationships can be described by the following regression equations:

Monserco uranium = 0.8606*MOEE uranium,
Monserco arsenic = 1.1862*MOEE arsenic,
Monserco antimony = 1.9523*MOEE antimony.

At the low end of the concentration range (close to background) the Monserco lab reported marginally higher levels of uranium and arsenic and marginally lower levels of antimony. The uranium levels at the higher end of the concentration range (several times background) were comparable. The difference between the labs was most pronounced in the two samples with high arsenic and antimony concentrations. Monserco reported arsenic concentrations up to 1.5 times higher and antimony concentrations almost twice as high as the MOEE LSB. The generally higher concentrations reported by Monserco were related to the use of NAA. Neutron Activation yields higher concentrations and a more accurate "total concentration" because this non-destructive process does not require the target analytes to be leached out of the sample by either a hydride (FAA) or acid digest (ICP). The lead results were most consistent between the two labs because the analytical processes were similar.

The LSB audit indicates that the results from the Monserco lab are acceptable, particularly towards the lower end of the concentration ranges where the majority of environmental samples fall. The larger difference in antimony concentrations at the high end is understandable

considering the different methodologies. However, since both the MOEE background and clean-up guidelines are very low, the higher reported antimony levels at the upper concentration range would not create a problem with false guideline exceedences.

Results of Analyses

Table 2 summarizes the uranium, arsenic, antimony, and lead data for all 12 schools. Even though the LSB conducted only a 25% analytical audit, because the Monserco samples were submitted in duplicate and the LSB audit was selected from every fourth sample, the overall result was that MOEE data were available for every second sample site, or for 9 of the 12 schools.

Large areas of Port Hope have elevated surface soil uranium concentrations as a result of decades of atmospheric emissions from the Cameco uranium refinery. Therefore it was not surprising to find six of the 12 schools with uranium concentrations exceeding the background-based MOEE OTR soil guideline[Ref.7] of 2.1 µg/g (**O**ntario **T**ypical **R**ange, see Appendix 2). The uranium contamination on the schools generally fell within the expected range, based on town-wide sampling conducted by the MOEE in 1986[Ref.1] and the LLRAWMO in 1994[Ref.2]. The only obvious exception was the front lawn of the Port Hope High School, which had an average of 4.1 µg/g uranium, or about twice what was expected based on the earlier sampling. By comparison, the soil from the football field at Port Hope High averaged 2.1 µg/g uranium, which is "normal" for that area of town. Despite the many (and expected) exceedences of the uranium OTR guideline, other than confirming that it is source-oriented contamination and not of natural origin, there is no significant environmental consequence to these marginal elevations. Uranium is not ecotoxic (toxic to plants, terrestrial, and aquatic organisms) below about 300 µg/g[Ref.8] and both the MOEE Port Hope Health Risk Assessment conducted in 1991[Ref.10] and the risk assessment studies sponsored by Health Canada[Ref.9] concluded there is no health concerns at soil uranium concentrations in the 200 to 400 µg/g range.

Arsenic is also a contaminant that has been deposited across significant areas of Port Hope as a result of historic uranium refinery emissions. However, the extent of contamination is less than that of uranium, being concentrated mostly in the southern part of town below Lakeshore Rd. in the west, Walton St. in the town centre, and Ward St. in the east. Like uranium, the soil arsenic concentrations at the schools were generally as expected. St Mary's school was the exception. The St. Mary's play ground was across the footbridge in the north end

of the park associated with the Lions Recreation Centre. The arsenic concentrations averaged between 28 and 30 µg/g in this park, which is higher than expected based on earlier MOEE sampling (about 20 µg/g[Ref.1]), and higher than both the background-based OTR (17 µg/g) and MOEE effects-based soil clean-up guideline[Ref.11] (25 µg/g - see Appendix 3). The arsenic clean-up guideline is based on plant toxicity, which is lower than the health-based level.

Soil lead concentrations fell into predicted ranges at 11 of the 12 schools, with St. Mary's school being the exception. Soil lead concentrations in the north end of the Lions Recreation Centre park were consistently elevated and ranged up to 740 µg/g. This is far higher than what naturally occurs in urban parkland (98 µg/g[Ref.7]) and more than three times higher than the health-based clean-up guideline (200 µg/g[Ref.11]). This is the first indication that soil lead contamination is a concern in an area of Port Hope other than adjacent to the river mouth and a few properties along Alexander St.

The natural background range of antimony in Ontario soil is quite low (0.43 µg/g[Ref.7]), which is close to the analytical detection limit. Six of the 12 schools had soil antimony concentrations that were marginally elevated relative to the background-based OTR guideline. These exceedences were a surprise because the normal variation of antimony in soil is very narrow, the natural background is very low, and antimony has not previously been identified as a regional contaminant in Port Hope; although admittedly, the MOEE cross-town 1986 soil sampling[Ref.1] did not include antimony analyses. Like lead, soil antimony contamination was confirmed in the 1987[Ref.1] and 1991[Ref.12] Phytotoxicology surveys on selected locations adjacent to the river mouth and along Alexander St. Other than being higher than normal, the elevated antimony concentrations at these six schools are environmentally inconsequential because they are only marginally higher than background and substantially below the health-based clean-up guideline. In contrast, a seventh school, St. Mary's (Lions Recreation Centre park), had soil antimony concentrations ranging from 280 µg/g to 443 µg/g, which is up to 30 times higher than the health-based soil clean-up guideline of 13 µg/g.

Unlike the NAA procedure used by the Monserco lab, which yields results for selected elements (in this case uranium, arsenic, antimony, and lead, as requested by the Cameco purchase order), the ICP-MS analytical procedure used by the LSB yields a string of additional elements. Table 3 summarizes the MOEE results for 20 elements from the audit subsamples. These data are from single samples only, from nine of the 12 schools. In addition to the uranium, arsenic, antimony, and lead results already discussed, the zinc, barium, and strontium soil concentrations from St. Mary's (the Lions Recreation Centre park) exceeded the OTR guidelines. The health-

based clean-up guidelines were not exceeded. No guidelines were exceeded for these additional elements at any of the other 11 schools.

The use of the Lions Recreation Centre park as a play ground for St. Mary's was a temporary measure. Virtually all of the St. Mary's play ground space was taken up by portables to accommodate extra students during the construction of St. Anthony's. This took place during the 1995/96 school year. In July 1996, when the school yard sampling was conducted, the portables were still in place at St. Mary's. The only play area at St. Mary's was around the play ground equipment in the northwest corner of the property. The ground around the play ground equipment was covered in pea gravel, and the ground elsewhere on the property around the portables was paved. Therefore, there was no opportunity to collect soil samples in the school yard proper, and it was apparent that the north end of the adjacent park across the footbridge (Lions Recreation Centre) was used by St. Mary's students as an outdoor play ground.

Only the north end of the Lions Recreation Centre park was sampled, because as previously explained, the 1996 sampling program was intended as a screening-level program. Additional sampling is required to characterize the extent of the soil contamination in this municipal park.

The Source of the Soil Contamination at the Lions Recreation Centre

The source of the uranium and arsenic contamination in the surface soil at the Lions Recreation Centre park is historical atmospheric emissions of these elements from Cameco and it's predecessor industries. The presence of antimony, lead, barium, strontium, and zinc contamination was unexpected and the source was unknown. These elements are not associated with the known current or historical emission or waste process streams from Cameco. The lead and antimony contamination around the river mouth, and to a lesser degree at selected sites along Alexander St., is believed to be associated with process waste disposal from the historical Crane foundry. A foundry operated at the river mouth area for perhaps as long as 100 years. Before Crane, it was known as Standard Sanitary, and before that it was called Port Hope Sanitary. Although this foundry would certainly have produced atmospheric emissions, the nature of these emissions and the potential for local soil contamination would be conjecture. However, it is common knowledge among long-time Port Hope residents that the foundry produced large volumes of cinder-like aggregate waste, and that this waste was used to fill low ground around town, and that people also used it for residential construction projects. MOEE sampling of what

was believed to be foundry waste at the river mouth area showed this material to be significantly contaminated with lead and antimony in a ratio of about 1:1[Ref.12]. In uncontaminated soil the lead:antimony ratio is more than 200:1[Ref.7] The lead:antimony ratio of soil at the Lions Recreation Centre park ranges from about 1:1 to about 2:1, which strongly suggests a foundry waste origin.

Discussions with the LLRAWMO confirmed that gamma radiation and other solid radioactive waste have not been detected in Lions park. Testing during the LLRAWMO's on-going construction monitoring program revealed glass, bricks, and other unconsolidated debris in excavated soil from several residential projects on Gifford St. immediately south of the park. This is consistent with anecdotal information that the area currently occupied by the Lions Recreation Centre was low land that was used as a municipal dump, known locally as Sandy Dump, until some time between 1910 and 1918. Although no municipal garbage was dumped after that time, the area received fill of unknown origin continuously until the early 1940s. This fill included quantities of cinder-like material, but witnesses could not be confident that it was foundry waste or coal cinders. Likely it was a combination of both. Coal cinders were routinely disposed of by residents in local dumps, and the Lions park was a low area close to the foundry site which would have been an attractive site for foundry waste disposal. By the mid 1940s the Lions park area had obtained it's current elevation and no signs of the municipal dump or other disposal activities were evident. The Lions Club sodded the site and presented it to the town as the Lions Recreation Centre in the late 1940s. This information is consistent with observations made at the park during the July 1996 sampling. The north end of the park was grassed, the elevation was level, the area appeared undisturbed, and the park trees were estimated at between 40 and 50 years old.

There had been a swimming pool and a wading pool in the north part of the Lions park in the area adjacent to the 1996 sample site. Material excavated during the construction of the pools may have exhumed contaminated fill buried at depth, subsequently contaminating the surface soil in the north end of the park. This assumes that surface soil across the park was/is not already contaminated, which cannot be confirmed without additional sampling.

Conclusions

Surface soil was sampled from the main play areas of 12 Port Hope schools in July 1996. Uranium and arsenic concentrations were within the expected range at 11 of the 12

schools, based on previous studies conducted by the MOEE and the LLRAWMO. Soil antimony concentrations marginally exceeded the background-based OTR guideline at some play grounds at six schools. Surface soil at the north end of the Lions Recreation Centre park, which was sampled as the play ground for St. Mary's school, had lead and antimony concentrations that exceeded the health-based soil clean-up guidelines, and uranium, arsenic, barium, zinc, and strontium concentrations that exceeded the OTR guidelines. The source of this contamination is almost certainly historical disposal of foundry waste (*Crane, previously Standard Sanitary, not Cameco refinery waste*), municipal waste dumping, and general land filling in the park area that took place since before the turn of the century to about the early 1940s. The extent of the contamination in the Lions Recreation Centre park is unknown, as only surface soil (0 to 5 cm) from the north end of the park was sampled.

The MOEE soil clean-up guideline for lead is targeted specifically at protecting young children, as they are more sensitive to the well known potential health effects of lead exposure. The potential health effects of antimony exposure on children are less clearly understood. Unlike buried radioactive contamination that can result in radon gas emissions at the surface, inorganic contamination (like lead and antimony) buried at depth does not create a potential health problem for children using the park as long as the surface soil layer is clean. Children are exposed to the contaminant by physical contact with contaminated soil, or through inhaling contaminated dust that gets stirred up by play activity or ground level winds. However, at least in the north end of the park where sampling was conducted, lead and antimony contamination exists in the surface soil and therefore children using the park during non-snow cover conditions are potentially at risk of exposure. Until subsequent sampling defines the extent and severity of surface soil contamination, restricting young children's access to the park may be warranted.

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Table 1
The Locations of Phytotoxicology Surface Soil Samples Collected from 12 Port Hope Schools, July 10, 1996.

School	Sample Site Description	GPS UTM Location*	
		Easting	Northing
Dr. L.B. Powers	Sandy-grassy area around the southwest playground.	7-17-431	48-70-335
Dr. L.B. Powers	East lawn by the flagpole.	7-17-349	48-70-359
Trinity College	Main football field, east campus, western most of two fields.	7-17-870	48-71-079
Trinity College	Main soccer field, east campus, southern most of two fields.	7-17-710	48-71-030
Trinity College	Practice soccer field, west campus.	7-17-788	48-70-699
George Hamilton	Ball diamond, southwest edge of field.	7-12-919	48-72-499
George Hamilton	Lawn area around the playground adjacent to the school.	7-12-966	48-72-493
Scriven Christian	Lawn area around the playground equipment.	7-14-533	48-70-943
St. Anthony's	Ball diamond.	7-15-530	48-69-906
Howard Jordon	Most westerly soccer field.	7-15-394	48-70-378
Howard Jordon	Lawn area around the playground equipment.	7-15-459	48-70-501
Port Hope High	Southeast lawn area by the front door.	7-15-887	48-70-415
Port Hope High	Football field.	7-15-867	48-70-593
M.S. Hawkins	Soccer field.	7-16-566	48-70-328
Central	Sandy area in the southeast corner of the lower play yard.	7-16-847	48-70-163
Central	Grassy area of the upper play yard.	7-16-669	48-70-154
Beatrice Strong	North playground	7-17-935	48-71-417
Beatrice Strong	Soccer field	7-17-929	48-71-221
Beatrice Strong	South playground	7-17-952	48-71-210
St. Mary's	Over the footbridge, north end of Lions Recreation Centre.	7-16-643	48-69-746

*Global satellite positioning using the Universal Transverse Mercator grid (Zone 17), the location is fixed to within +/- 1 metre. See the text for more details on how the actual sample site was defined.

Table 2: Surface Soil (0 to 5 cm) Uranium, Arsenic, Antimony, and Lead Concentrations of the Main Play Yards from Port Hope Schools.

School	Uranium		Arsenic		Antimony		Lead	
	MOEE	Monserco	MOEE	Monserco	MOEE	Monserco	MOEE	Monserco
L.B. Powers - SW playground	**2.3**	**2.2**	3.0	3.5	**1.1**	**0.63**	22	23
L.B. Powers - E lawn by flagpole		**3.4**		6.0		**6.00**		27
Trinity College - football field, E campus	1.3	2.0	2.9	3.4	**0.7**	0.38	21	17
Trinity College - soccer field, E campus		2.0		4.8		**0.76**		14
Trinity College - soccer filed, W campus	**2.2**	**2.2**	3.4	3.3	**0.8**	**0.50**	20	13
George Hamilton - ball diamond		1.8		5.0		0.20		10
George Hamilton - playground	0.5	1.3	2.6	2.1	0.4	0.21	13	10
Scriven Christian Academy - playground		2.1		5.0		0.33		20
St. Anthony's - ball diamond	0.9	1.8	3.1	5.0	0.3	0.34	15	16
Howard Jordon - W soccer field		2.1		2.9		0.33		11
Howard Jordon - playground & portables	0.9	1.9	3.6	3.4	**0.5**	0.38	17	15
Port Hope H.S. - SE lawn, front door		**4.1**		2.8		**1.22**		30
Port Hope H.S. - football field	0.9	2.1	3.0	3.2	**1.1**	**0.82**	16	12
M.S. Hawkins - soccer field		**3.2**		6.0		**1.82**		35
Central - lower playground	0.6	1.8	2.2	3.3	**0.7**	**0.84**	10	11
Central - upper playground		2.2		1.9		0.28		15
St. Mary's - Lions Recreation Centre	**3.0**	**4.5**	**30**	**28**	**280**	**443**	**720**	**582**
Beatrice Strong - N playground		1.9		3.4		0.17T		10
Beatrice Strong - soccer field	0.7	2.0	1.2	3.6	**0.6**	**1.80**	17	6
Beatrice Strong - S playground		1.9		3.6		0.16T		7
MOEE - Uranium QA/QC	**24.2**	**20.2**	NA	10.8	NA	**14**	NA	58
MOEE - Arsenic, Antimony, Lead QA/QC	NA	2.1	15.4	**23.2**	**25.4**	**44**	**950**	**963**
MOEE OTR (Clean-Up) Soil Guidelines	2.1 (300*)		17 (25)		0.43 (13)		98 (200)	

OTR - Ontario Typical Range background-based soil guideline, see Appendix 2, Clean-up guidelines are effects-based, see Appendix 3. Shaded data exceed guidelines.
*No Clean-Up guideline, this is the lowest effects-based level based on bioassay studies using Ontario conditions.
NA - no analysis. All data are µg/g single (MOEE) or duplicate (Monserco) samples.

Table 3: Full Chemical Scan of MOEE Audit Samples.

Chemical	L.B. Powers SW Playground	Trinity College E Football Field	Trinity College W Soccer Field	George Hamilton Playground	At. Anthony's Ball Diamond	Howard Jordon Playground	Port Hope HS Football Field	Central Lower Yard	St. Mary's Playground	Beatrice Strong Soccer Field	MOEE Guidelines OTR (Clean-Up)
Beryllium	0.5W	0.6T	0.5W	0.5W	0.5W	0.5W	0.5W	0.5W	0.5W	0.5W	0.97 (1.2)
Magnesium	4,000	5,400	4,600	4,400	1,900	2,600	3,300	2,900	4,400	4,600	16,000 (NA)
Aluminum	10,000	15,000	14,000	14,000	8,500	9,000	8,400	9,300	7,000	12,000	27,000 (NA)
Calcium	50,000	9,500	10,000	16,000	6,100	15,000	14,000	21,000	56,000	12,000	58,000 (NA)
Vanadium	32	44	39	35	25	28	27	29	24	37	71 (200)
Chromium	18	27	25	22	12	13	13	15	17	22	62 (750)
Manganese	330	430	410	450	220	290	330	440	270	410	1,300 (NA)
Iron	15,000	20,000	18,000	18,000	12,000	14,000	14,000	14,000	16,000	18,000	33,000 (NA)
Cobalt	5.1	8.5	7.4	7.0	2.9	3.7	3.6	4.4	4.1	6.4	17 (40)
Nickel	9.7	15	14	12	6.4	6.3	6.3	7.9	11	12	32 (150)
Copper	12	16	15	10	5.0	5.0	6.0	6.0	33	9.0	65 (225)
Zinc	63	67	57	51	38	48	43	38	**550**	54	140 (600)
Molybdenum	0.5W	0.5W	0.5W	0.5W	0.5W	0.5W	0.5W	0.5W	0.6T	0.5W	0.85 (40)
Cadmium	0.3T	0.5T	0.4T	0.6T	0.3T	0.4T	0.2W	0.5T	0.4T	0.2W	0.84 (12)
Barium	64	110	99	79	35	35	43	65	**370**	80	180 (750)
Lead	22	21	20	13	15	17	16	10	**720**	17	98 (200)
Strontium	78	27	26	33	16	29	34	38	**86**	33	78 (NA)
Uranium	**2.3**	1.3	**2.2**	0.5T	0.9T	0.9T	0.9T	0.6T	**3.0**	0.7	1.9 (NA)
Arsenic	3.0	2.9	3.4	2.6	3.1	3.6	3.0	2.2	**30**	1.2	17 (20)
Antimony	**1.1**	**0.7T**	**0.8**	0.4T	0.3T	**0.5T**	**1.1**	**0.7T**	**280**	**0.6**	0.43 (13)

Data are µg/g, dry weight, single samples, all analyses conducted by MOEE Laboratory Services Branch.
OTR - Ontario Typical Range guidelines for urban parkland soil are background based, see Appendix 2.
Clean-Up guidelines for residential/park land use are effects-based, see Appendix 3. NA - guideline not available.
Data that exceeds either the OTR or clean-up guidelines are shaded.
W - analytical detection limit, essentially a zero response.
T - a measurable trace amount, interpret with caution.

Appendix 1: Comparison of Analytical Results: Monserco and MOEE Laboratory Services Branch.

	Monserco U	MOEE U	Ratio Mon:MOE	Monserco As	MOEE As	Ratio Mon:MOE	Monserco Sb	MOEE Sb	Ratio Mon:MOE	Monserco Pb	MOEE Pb	Ratio Mon:MOE
Sample 1	2.1	2.3	0.913	3.4	3.0	1.133	0.6	1.1	0.545	23	22	1.045
Sample 2	2.3	1.3	1.769	3.4	2.9	1.172	0.4	0.7	0.571	17	21	0.809
Sample 3	2.4	2.2	1.091	3.1	3.4	0.912	0.5	0.8	0.625	12	20	0.600
Sample 4	1.3	0.5	2.600	3.1	2.8	1.192	0.1	0.4	0.250	9	13	0.692
Sample 5	1.7	0.9	1.889	3.7	3.1	1.194	0.3	0.3	1.000	9	15	0.600
Sample 6	2.0	0.9	2.222	3.5	3.6	0.972	0.4	0.5	0.800	16	17	0.941
Sample 7	2.2	0.9	2.444	3.4	3.0	1.133	0.8	1.1	0.727	11	16	0.687
Sample 8	2.0	0.8	3.333	4.0	2.2	1.818	1.0	0.7	1.429	12	10	1.200
Sample 9	5.0	3.0	1.667	33	30	1.100	547	280	1.954	740	720	1.027
Sample 10	2.0	0.7	2.857	4.2	1.2	3.500	3.4	0.6	5.667	7	17	0.411
LSB QA/QC	20	24	0.833	23	15	1.533	45	25	1.800	963	950	1.013
Mean	3.9	3.4	1.965	8.0	6.4	1.424	56	28	1.397	165	165	0.820
Standard Deviation	5.4	6.8		10.2	8.7		183.8	83.6		343	335	
Variance	29.38	47.39		103.07	75.31		26857.55	7022.58		117586.65	112209.47	
t-test (p<)*	0.3111	(ns)		0.0495	(ns)		0.3032	(ns)		0.9485	(ns)	
R^2 (p<)	0.9413	(0.001)		0.9564	(0.001)		0.9998	(0.001)		0.9997		
Regression 0 Intercept**	0.8606			1.18821			1.9523			1.0183		

* two-tailed paired t test to determine if the two sample population means are different; results are not statistically different at P<0.05.
** using the equation y = mx, where m is the y intercept with the constant forced through 0; y is the independent variable (Monserco) and x is the dependant variable (MOEE) .
All data are µg/g single paired samples.
LSB - MOEE Laboratory Services Branch.

Appendix 2
Derivation and Significance of the MOEE "Ontario Typical Range" Soil Guidelines.

The MOEE "Ontario Typical Range" (OTR) guidelines are being developed to assist in interpreting analytical data and evaluating source-related impacts on the terrestrial environment. The OTRs are used to determine if the level of a chemical parameter in soil, plants, moss bags, or snow is significantly greater than the normal background range. An exceedence of the OTR_{98} (*the OTR_{98} is the actual guideline number*) may indicate the presence of a potential point source of contamination.

The OTR_{98} represents the expected range of concentrations of chemical parameters in surface soil, plants, moss bags, and snow from areas in Ontario not subjected to the influence of known point sources of pollution. The OTR_{98} represents 97.5 percent of the data in the OTR distribution. This is equivalent to the mean plus two standard deviations, which is similar to the previous MOEE "Upper Limit of Normal" (ULN) guidelines. In other words, 98 out of every 100 background samples should be lower than the OTR_{98}.

The OTR_{98} may vary between land use categories even in the absence of a point source of pollution because of natural variation and the amount and type of human activity, both past and present. Therefore, OTRs are being developed for several land use categories. The three main land use categories are Rural, New Urban, and Old Urban. Urban is defined as an area that has municipal water and sewage services. Old Urban is any area that has been developed as an urban area for more than 40 years. Rural is all other areas. These major land use categories are further broken into three subcategories; Parkland (which includes greenbelts and woodlands), Residential, and Industrial (which includes heavy industry, commercial properties such as malls, and transportation rights-of-way). Rural also includes an Agricultural category.

The OTR guidelines apply only to samples collected using standard MOEE sampling, sample preparation, and analytical protocols. Because the background data were collected in Ontario, the OTRs represent Ontario environmental conditions.

The OTRs are not the only means by which results are interpreted. Data interpretation should involve reviewing results from control samples, examining all the survey data for evidence of a pattern of contamination relative to the suspected source, and where available, comparison with effects-based guidelines. The OTRs are particularly useful where there is uncertainty regarding local background concentrations and/or insufficient samples were collected to determine a contamination gradient. OTRs are also used to determine where in the anticipated range a result falls. This can identify a potential concern even when a result falls within the guideline. For example, if all of the results from a survey are close to the OTR_{98} this could indicate that the local environment has been contaminated above the *anticipated average*, and therefore the pollution source should be more closely monitored.

The OTRs identify a range of chemical parameters resulting from natural variation and normal human activity. ***As a result, it must be stressed that values falling within a specific OTR_{98} should not be considered as acceptable or desirable levels; nor does the OTR_{98} imply toxicity to plants, animals or humans.*** Rather, the OTR_{98} is a level which, if exceeded, prompts further investigation on a case by case basis to determine the significance, if any, of the above normal concentration. Incidental, isolated or spurious exceedences of an OTR_{98} do not necessarily indicate a need for regulatory or abatement activity. However, repeated and/or extensive exceedences of an OTR_{98} that appears to be related to a potential pollution source does indicate the need for a thorough evaluation of the regulatory or abatement program.

The OTR_{98} supersedes the Phytotoxicology ULN guideline. The OTR program is on-going. The number of OTRs will be continuously updated as sampling is completed for the various land use categories and sample types. For more information on these guidelines please refer to *Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags, and Snow. MOEE Report Number HCB-151-3512-93, PIBs Number 2792.*

Appendix 3.
Derivation and Significance of the MOEE Soil Remediation Criteria (Clean-up Guidelines)

The MOEE Soil Remediation Criteria have been developed to provide guidance in cleaning up contaminated soil. They are not action levels, in that an exceedence of one or more of the criteria does not automatically mean that a clean-up must be conducted. A site clean-up may be conducted when a contaminated property is sold and/or the land use is changed. For example, the owner of an industrial property who plans to sell his/her land to a developer who intends to build residential homes can use the Remediation Criteria to clean up the soil to meet the residential land use criteria. This will allow the site to be reused for residential land-use without concern for adverse effects.

When contamination is found at a site where a change in land-use is not planned, the criteria may be used to assist in making decisions about adverse effects and the need for remediation. This is different from the previously described situation where a decision to change the land-use has already been made and the level of remediation required to rule out the potential for adverse effects is established by the new land use. Decisions on the need to undertake remedial action when the criteria are exceeded, and where the land use is not changing, require consideration of factors such as:

- the demonstrated presence or likelihood of an adverse effect (on and off property);
- an understanding of the type of protection provided by the criteria gained through knowledge of the exposure pathways and receptors which were considered in the development of the criteria, and through understanding how that combination of pathways and receptors relate to those which could be found at the site;
- an understanding of the relationship between dose and health response for sensitive receptors from all exposure pathways, including the safety and uncertainty factors that have been used in the development of the criteria;
- an understanding of the environmental characteristics of the contaminants and of the site conditions that could influence the migration of the contaminants and how this effects their exposure and response characteristics.

In each case, the decision to undertake or not undertake site remediation should entail all of these factors plus any additional factors specific to the site in question. When the decision is made that remedial action is needed, the criteria can be used as clean-up targets. If these criteria are unacceptable to the proponent undertaking the remediation, they have an option to develop local back-ground-based criteria or conduct a site specific risk assessment.

The Soil Remediation Criteria are effects-based concentrations set to protect against the potential for adverse effects to human health, ecological health, and the natural environment, whichever is the most sensitive. By protecting the most sensitive parameter the rest of the environment is protected by default. There are different Soil Remediation Criteria for soil texture, soil depth, and ground water use. The criteria have also been established so that there will not be a potential for adverse effects through contaminant transfer from soil to indoor air, from ground water or surface water through release of volatile gases, from leaching of contaminants in soil to ground water, or from ground water discharge to surface water. However, use of these criteria may not ensure that corrosive, explosive, or unstable soil conditions will be eliminated.

The Soil Remediation Criteria were developed from published U.S. EPA and Ontario environmental data bases. Currently there are criteria for about 25 inorganic elements and about 90 organic compounds. Criteria were developed only if there were sufficient, defendable, effects-based data on the potential to cause an adverse effect. All of the criteria address human health and aquatic toxicity, but terrestrial ecological toxicity information was not available for all elements or compounds. The development of Soil Remediation Criteria is a continuous program, and criteria for more elements and compounds will be developed as additional environmental data become available. Similarly, new information could result in future modifications to the existing criteria.

For more information on the Remediation Criteria please refer to the *Guideline for Use at Contaminated Sites in Ontario. Revised December 1996*, Ontario Ministry of Environment and Energy, PIBs 3161E01, ISBN 0-7778-5905-X.